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Analysis

Identifying Links between Economic Opportunities and Climate Change Adaptation: Empirical Evidence of 63 Cities

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ABSTRACT

This paper empirically explores the linkage between the economic opportunities and climate adaptation and other antecedents in cities. Our dependent variable includes the economic opportunities identified by the cities; our independent variables are the adaptation plans, adaptation actions, climate change risks, incentive types, and incentivized stakeholders. To explore the effects of climate change risks, adaptation plans, adaptation actions, incentive types, and incentivized stakeholders, we used polychoric factor analysis and logistic regression analysis. The results show that a city's climate change adaptation plan and GDP have significant positive relationships with the economic opportunities present in the cities. Meanwhile, climate change risks also have a positive relationship with economic opportunities. Furthermore, economic opportunities present in cities have a negative relationship with three variables: one group of climate actions and two groups of stakeholders. This paper also further discusses the possible effects of incentives in the case of climate change in cities.

1. Introduction

Many of the climate risks encountered in cities require a successful climate change adaptation, and IPCC calls for efforts to ensure efficient and cost-effective adaptation actions (IPCC, 2014). Adaptation is emphasized as one of the essential climate change measures by the United Nations Framework Convention on Climate Change (UNFCCC, 2007) and it is considered relevant for policy-makers (Vale, 2016). The definition of adaptation recognized by the UNFCCC and recorded in the Fifth Assessment Report of IPCC reads as "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2014, p.118). Climate change adaptation planning is the phase preceding implementation. Policy is a vision of decision-makers and a plan is the realization of the vision of decision making (Haasnoot et al., 2013). A climate change adaptation plan is a strategic plan with the overarching objective to reduce vulnerability and climate change impacts. Climate change actions are the practices of the adaptation plans (IPCC, 2014).

Climate change adaptation is critical for long-term sustainability of economies, societies, and environments (O'Brien et al., 2012). It is crucial for cities and city-level climate change adaptation to address impacts and economic costs across different sectors due to climate change (Hunt and Watkiss, 2011). Recognizing its importance, local governments have started to initiate climate change adaptation plans and invest in adaptation (Woodruff and Stults, 2016).

In this paper we analyze the adaptation actions from an economic perspective. For this purpose they can be categorized according to three economic principles: no-regret, low-regret, and win-win adaptation (Sainz de Murieta et al., 2014; UKCIP, 2007). Besides possible benefits, adaptation can sometimes also have trade-off effects with mitigation, such as installing air conditioning to adapt to a warmer climate could result in higher carbon emissions and urban heat island effects. The costs and benefits are also described in a trade-off relationship whose benefits include the potential damage savings (every increased expectation of disaster adds to the present value of benefits, as a calculation of the damages avoided) and potential gains, together with a calculation of costs associated with the adaptation measures (Heuson et al., 2014). Research on the economics of climate change adaptation often focuses more on costs rather than benefits, including costs of adaptation measures and costs of damage prevention in the future (Heuson et al., 2014; Hübler et al., 2008; Stern, 2007). Adaptation sometimes requires initial capital investments; therefore, there are different ways to calculate the economic outcomes of adaptation: cost-benefit analysis, net present value calculation, or cost-effectiveness

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analysis. Studies on payments or valuations of ecosystem services are emerging (Brink et al., 2016; Dawson and Martin, 2015; De Groot et al., 2002; Derbek et al., 2015; Farley and Costanza, 2010; Grêt-Regamey and Kytzia, 2007; Gutman, 2007), for instance, which study the effect of ecosystem service valuations on mitigation efforts (Balderas Torres et al., 2015). Comparatively, there is less focus in empirical studies on finding relationships between economic benefits and climate change adaptation. The existing empirical case studies focusing on benefits mainly address agriculture, presenting results where adaptation measures show positive gains in farm net returns and losses due to inaction towards climate change (Singh et al., 2015).

Our sample questionnaire was addressed to local governments to provide information on the incentives to climate change efforts (CDP, 2012); in academic literature, there is a gap in research regarding the effects of these incentives on climate change efforts in cities. What we do not know are the effects of incentives on local climate change policy implementation in cities. But why is it important to study the impacts of incentives on climate change policy in local governments? The topic of assessing the effects of incentives is important because economic incentives are widely applied and it is especially relevant for topics regarding environmental issues (Neuteleers and Engelen, 2015). In fact, studies have shown that there are both negative and positive effects, namely crowding-out and crowding-in effects of economic incentives (Rode et al., 2015). It is important to know whether the effects of such incentives encourage or discourage motivations to ensure efficient investments. The effects have been studied and categorized into two main effects: crowding-in and crowding-out effects (Neuteleers and Engelen, 2015; Rode et al., 2015; Sandel, 2013; Varghese et al., 2013). Crowding-out effects describe the fact, that economic incentives undermine or reduce motivation of people to engage, while crowding-in effects reinforce or strengthen people's motivation to devote their efforts (Neuteleers and Engelen, 2015; Rode et al., 2015; Sandel, 2013). Even though there are researchers studying the crowding-out effects in the areas of resource use, mobility, consumption decisions, and pollution, there is relatively little literature focusing on incentives and economic instruments in climate change adaptation (there are, however, some studies focusing on insurance and trade-related instruments) (IPCC, 2014; Rode et al., 2015; Sainz de Murieta et al., 2014).

In order to have a worldwide sample, the CDP (Carbon Disclosure Project) database is chosen as the questionnaires answered by cities worldwide in 2012 provided answers concerning cities' climate change risks, plans, adaptation actions and incentives. Furthermore, data concerning cities' temperature and precipitation are obtained from the World Meteorological Organization database. Data of GDP estimates are from several city-level reports and databases. In the end, 63 cities fit these requirements.

The following section reviews the literature on the economics of climate change adaptation, incentives and theoretical foundation of motivation crowding theory. Section 3 illustrates our research methods and data, followed by Section 4 which discusses the results and is followed by the discussion of limitations of this research and hints for future research in Section 5. The last section concludes our paper with our main findings.

2. Literature Review and Theoretical Considerations

The discipline of economics plays a key role in the field of climate change adaptation due to its contribution of tools and methods which provide potential answers and solutions which are crucial to the adaptation policy (IPCC, 2014). However, the economics of climate change adaptation is still a relatively young field of research and currently is growing at a considerable pace, already exhibiting a wide range of methodological approaches and research questions (Heuson et al., 2014). Further advances in the understanding of consequences of climate adaptation policy are especially needed in research (Burke et al., 2016). This has generated the motivation of this research to use empirical data from cities to better understand the outcomes of climate change adaptation to answer the main research question: How are climatic, demographic, and economic variables associated with economic opportunities in terms of climate change adaptation in cities? To answer the research question, the following section of the paper deduces a series of hypotheses along with descriptions of each variable.

Current climate change adaptation literature focuses on physical impacts of potential adaptation responses, such as protection measures against storm surges and floods. For instance, the empirical results link past flood damage experience and damage expectations to climate change actions (Osberghaus, 2015). The existing research rarely uses risks as a function in the analysis (Lasage et al., 2014). Two opposing theories concerning risks explain different effects they could have on the cities. First, the risks could cause possible economic and ecological damages due to the experienced hazards. However, the experienced hazards could better prepare cities for future climate change planning and thus make them more resilient in their local economy due to their preparedness for climate change (Huang-Lachmann and Lovett, 2015). We are eager to determine whether risks themselves have any effects, especially in the form of damage to local economies. Therefore, climate change risks are also chosen as a variable in our regression analysis, to test the hypothesis whether a city's climate change risks are associated with its economic opportunities.

When it comes to adaptation as a variable, the studies usually analyze adaptation as one general variable. However, there are different kinds of adaptation actions with different functions. According to IPCC, adaptation actions present diverse options in cities: sea level rise, water, urban flooding, energy, health, and combined sectors of the adaptation options (IPCC, 2014). It is important to distinguish these and investigate the details of different adaptation actions in order to provide more precise information for policymaking and implementation efforts due to budget allocation at the national or local levels (Trærup and Stephan, 2015). Therefore, in our study we differentiate between the adaptation plans and actions by coding them separately to firstly test whether a city's climate change adaptation plan is associated with its economic opportunities. Then, to explore the details of adaptation actions carried out in cities, a factor analysis is used to allocate the actions to different groups for our analysis. There are several ways to categorize actions of adaptation, and IPCC (2014) differentiates three main categories: physical, social and institutional. For instance, physical actions include the engineered and built environment, technological and ecosystem based adaptation, and services (IPCC, 2014). Social actions include educational, informational, and behavioral actions while institutional adaptation includes economic, legal and governmental actions (IPCC, 2014). This categorization is used to test whether a city's climate change adaptation actions are associated with its economic opportunities. Climate adaptation actions could sometimes provide short-term benefits but nevertheless, lead to adverse consequences in the long run (Warner et al., 2012; Warner and van der Geest, 2013).

Furthermore, economic studies focusing on climate change adaptation tend to focus more on the hard adaptation measures and may lead to a bias which neglects potentially critical soft measures needed to facilitate adaptation (Agrawala and Fankhauser, 2008). Investments in soft measures are rarely assessed in the literature. Other relevant indicators related to human, social, natural, physical, and financial capitals should also be considered (Brown et al., 2015). Economic viability, individual or institutional variables, and benefits should also be included in variables to be assessed (Nambi et al., 2015). Therefore, economic opportunities are chosen as the dependent variable.

In addition to climate change risks, climate adaptation plan, and actions, it is also pointed out that information, incentives, and resources are also very important for decision making regarding adaptation policy (Markandya et al., 2014). The proper information is needed for the local governments to understand the climate change impacts. The costs and benefits of available adaptation options should be made available to the local governments for their implementation. However, the

empirical studies have shown that local governments often lack this information (Markandya et al., 2014). This paper attempts to close this gap in research. Given the need and urgency of climate change adaptation, efforts to incentivize adaptation implementation have started to emerge. International, regional, national, and local institutions have started to use different mechanisms to mainstream and encourage adaptation actions. Therefore, studies on incentives of climate change actions are beginning to appear (Neuteleers and Engelen, 2015; Rode et al., 2015; Sandel, 2013; Varghese et al., 2013). Incentives are useful because people often respond to them (Mankiw, 2012; Sandel, 2013).

Incentives provided to managers in public or private sectors to carry out climate change plans and actions could also bring benefits, as could awareness among communities and citizens. Even though there is a quite strong research stream regarding incentives, more studies are needed which discuss the potential of market-based instruments such as incentives in science and how it undermines or enforces environmental protection empirically (Neuteleers and Engelen, 2015). The importance of focusing on variables of incentives is stressed as the incentive is related to the willingness to promote public adaptation and these interests may have an impact on the extent of adaptation as well as the types of adaptation (Gawel et al., 2012; Hallegatte et al., 2011; Heuson et al., 2014; Yohe, 2001). At the same time, researchers call for the cautious use of money because the 'talking money' market-based valuation could corrupt the commitments and undermine the efforts of environmental protection (Neuteleers and Engelen, 2015). The IPCC (2014) has pointed out in their fifth assessment report that incentives have to be carefully designed in a way to ensure efficient and cost effective outcomes while avoiding perverse results. Sandel (2013) discusses the limitations of incentives from the perspective of intrinsic motivation. First of all, providing monetary incentives could lead to potential harms of replacing an intrinsic motivation with an external one (Sandel, 2013, p. 59). Why is this relevant to economics and climate change? Economic incentives have been widely used worldwide and it is important to find out whether they really support the advancement of climate change policy (Rode et al., 2015), or do financial incentives have trade-off effects on climate change risks such as flooding (Hudson et al., 2016). Additionally, Sandel (2013) reminds us that there are two questions we should ask ourselves when it comes to the mechanism of monetary incentives: (a) Do the monetary incentives really work; and (b) What values and attitudes do we change with such monetary incentives? Sandel (2013) explains that these two questions represent the perspectives of economists as well as moralists (p. 60). Certainly this is quite relevant to the climate change adaptation because it also consists of two important perspectives. The first point concerns the efficiency and effectiveness of the costs. Secondly, why do we adapt to climate change? Is it because of an external economic incentive? Or should it be an intrinsic urgency due to one's recognition of future climate impacts? The danger of imposing incentives on moral norms could mean putting a price on goods we consider priceless, such as stable climate. Therefore, it is especially crucial to be cautious when attempting to achieve the goals through incentives. Research which attempts to explain whether putting a price on an activity will crowd out nonmarket norms is needed (Sandel, 2013, p. 79). The empirical studies of crowding effects in a biodiversity context show both negative and positive outcomes (Neuteleers and Engelen, 2015; Rode et al., 2015; Sandel, 2013; Varghese et al., 2013). The negative crowding-out effects include the control aversion (feeling controlled), image change, internal satisfaction reduction, moral responsibility release, compensation (payments seen as environmental indulgences), cognitive concept change, and change from moral obligation to one of profit (Andreoni, 1990; Bénabou and Tirole, 2005; Bowles, 2008; Bowles and Polania-Reyes, 2012; Deci and Ryan, 2000; Frey and Stutzer, 2006; Gneezy et al., 2011; Goodin, 1994; Neuteleers and Engelen, 2015; Rode et al., 2015; Vatn, 2010).

The positive effects, also described as crowding-in effects, include the symbolic appreciation of people's efforts, attitude improvement, increased trust in regulations and institutions, and increased desirable societal action (Rode et al., 2015). One of the main arguments calling for a cautious use of market mechanisms is their corrosive effect: the market incentives could sometimes be strong enough to crowd out the moral norms. From an environmentalist's point of view, environmentally friendly behaviors could arise from moral norms such as societal virtue or awareness, and they are of great value. Economically, the loss of such social values could result in higher costs to buy such a sense of civic obligation for a better environment (Sandel, 2013, p. 119). Sandel (2013) argues that monetary incentives could weaken the commitment and motivation to protect the environment, which could be intrinsically worth more than the incentives offered. The main idea of researching the intrinsic motivation on climate change is to look at the topic of incentives with more than just the cost-effectiveness perspective, but to find real efficient schemes to motivate stakeholders to take climate change actions. Sandel (2013) proposes the theory of moral limits on limitation of incentives and the paper serves as an attempt to provide more empirical evidence on effects of incentives and linkages between the economy and climate change efforts. Some studies tackle the effects of monetary incentives in environmental protection (Neuteleers and Engelen, 2015; Rode et al., 2015; Sandel, 2013; Varghese et al., 2013). The findings of the existing studies present one important general conclusion: a call for empirical studies which consider socio-economic aspects (van den Bergh, 2008). Types of incentives and stakeholder groups entitled to incentives are coded in the study to test whether a city's monetary and non-monetary incentives for implementing climate actions are associated with its economic opportunities. Then we test whether stakeholder groups entitled to incentives are associated with economic opportunities. As a result, four stakeholder groups are identified according to the factor analysis: management (energy managers, environmental and sustainability managers, head of departments and facility managers), private actors (businesses and citizens/residents), employees and administrative actors (e.g. city agencies).

Variables concerning climate are important indicators (Brown et al., 2015), while it is equally important to include socio-economic variables, such as population, GDP (Kebede et al., 2015). On the other hand, non-market values of environmental variables should also be considered (Andreopoulos et al., 2015). Studies also suggest that variables should include climatic and non-climatic indicators (Galicia et al., 2015). Climatic data such as precipitation and temperature could be included as variables (IPCC, 2014; Kirchner et al., 2015; Lei et al., 2014). Daily weather conditions as well as seasonal and long-term climate change are important, especially for weather-dependent sectors (Hopkins, 2014). In order to consider these influences we integrate a series of questions into our analysis: Are climatic variables (such as average temperature, average rainfall, and climate change risks) associated with economic opportunities in cities? Is a city's population associated with economic opportunities from climate change adaptation in cities? Is a city's GDP associated with its economic opportunities? Therefore, we have included precipitation, temperature, population, and GDP as our control variables.

Based on our literature review and the deduced theoretical considerations, we will focus on the following variables in our analysis: climate-related variables (average temperature, average rainfall, and climate change risks); adaptive planning and capacity variables (climate adaptation plan and adaptation actions); one demographic variable (population); and economic variables (GDP, economic opportunities, incentives and incentivized stakeholders in cities).

To test the hypotheses described, the logical regression analysis including all variables mentioned above is as follows:

$$\text{Logit (Economic Opportunities)} = \beta_0 + \beta_1 \text{ Climate change risks} + \beta_2 \text{ Climate change adaptation plan} + \beta_3 \text{ Climate change adaptation actions} + \beta_4 \text{ Incentivized stakeholders} + \beta_5 \text{ Incentive types} + \beta_6 \text{ GDP−Control} + \beta_7 \text{ temperature−Control} + \beta_8 \text{ precipitation−Control} + \beta_9 \text{ population−Control} + \varepsilon,$$

where the betas in the variables of adaptation actions, incentivized stakeholder groups, and incentive types are vectors.

3. Material and Methods

3.1. Sample and Coding of Questionnaires

The input data for our analysis includes the 63 questionnaires responded to by the cities in 2012 and disclosed in the Carbon Disclosure Project (CDP) database. The sample[1] (as shown in Fig. 1) includes 5 cities from Africa, 10 cities from Asia, 17 cities from Europe, 22 cities from North America, 7 cities from South America, and 2 cities from Oceania.

Firstly, a content analysis is carried out to code the answers from the questionnaires. We have coded the questions related to our researched variables, namely risks of climate change, adaptation to climate change (including plans and actions), incentive structures (types of incentives and incentivized stakeholders), and the economic opportunities identified in the cities.

The coded questions include:

Climate related (including risks, adaptation plan, and actions):

- "What are the experienced effects or expected significant physical risks of climate change in your city?"
- "Do you have a plan for increasing your city's resilience to the expected physical effects of climate change?"
- "What are climate adaptation actions carried out in your city to reduce vulnerability and expected physical effects of climate change?"
- "Please describe the actions you are taking to reduce the risk to your city's infrastructure, citizens, and businesses from climate change as identified in the Risks Module."

Economic related (including incentivized stakeholder groups and types of incentives and economic opportunities):

- "Who is entitled to benefit from these incentives [for individual (or departmental) management of climate change issues]?"
- "The type of incentives?"
- "Does climate change present any economic opportunities for your city?"

Regarding the questions such as risks of climate change, adaptation plan, and economic opportunities, the responding cities had the opportunity to answer the yes-no questions along with the option of "don't know". Any response in the questionnaires which was not positive will be coded as negative to follow a conservative approach. In addition to the yes-no questions, cities are able to provide more details regarding the adaptation actions which have been carried out. In terms of questions related to incentives, they would provide details about what incentives are provided to which groups of stakeholders.

[1] The sample of 63 cities include Abidjan, Addis Ababa, Amsterdam, Atlanta, Austin, Bangkok, Basel, Berlin, Bogotá, Buenos Aires, Caracas, Changwon, Chicago, Columbia, Copenhagen, Curitiba, Dallas, Denver, Dublin, Durban, Guadalajara, Hamburg, Helsinki, Hong Kong, Houston, Jakarta, Kaohsiung, Karachi, Lagos, Las Vegas, London, Los Angeles, Madrid, Manchester, Melbourne, Miami, Moscow, New York, Oristano, Paris, Philadelphia, Phoenix, Pietermaritzburg, Portland, Riga, Rio de Janeiro, Rome, Rotterdam, San Diego, San Francisco, San Salvador, Santiago, Sao Paulo, Seattle, St Louis, Stockholm, Sydney, Taipei, Tokyo, Toronto, Vancouver, Warsaw, and Yokohama.

3.2. Factor Analysis

Since the variables of adaptation actions, incentivized stakeholders, and incentive types have a large number of coding items in the questionnaires, a factor analysis is carried out to load the items into groups for the following regression analysis.

3.2.1. Method of Factor Analysis

There are in total 28 variables in the category of climate change actions. Meanwhile, the categories of incentive types and incentivized stakeholders have 10 variables each. In our analysis, we have applied factor analysis to overcome the limitation of low number of coding in each category. The factor analysis procedure was able to provide the highest correlations between a factor score and the corresponding factor and, hence, maximizes validity (DiStefano et al., 2009). Therefore, before we carry out a regression analysis to determine the significant relations among variables, we firstly would need to conduct an exploratory factor analysis to reduce the variables into a small number of factors and identify latent cause and effect relationships. The idea behind the factor analysis is to find out whether the correlation between p variables is caused by $k < p$ unobserved variables. The latent factors should be easily interpretable and should explain the variability of the original data. The procedure of factor analysis is as follows (Hirzel et al., 2002): (1) Selection of variables and computation of the correlation matrix; (2) Extraction of factors and determination of factor loadings; (3) Number of factors; (4) Interpretation of factors; (5) Computation of factor scores.

In the first step, we selected the variables and correlation matrix. Due to the homogeneous nature of the sample, we checked the distribution of data, carried out a Bartlett-Test, and also checked the Kaiser, Meyer, Olkin measure of sampling adequacy (Olkin and Pratt, 1958). Due to the design of the questionnaire, the obtained data were dichotomous.

In our case, both observed variables are dichotomous. Therefore, it was not possible to use a Pearson product-moment correlation coefficient (Bonett and Price, 2005). Tetrachoric correlation, as a polychoric

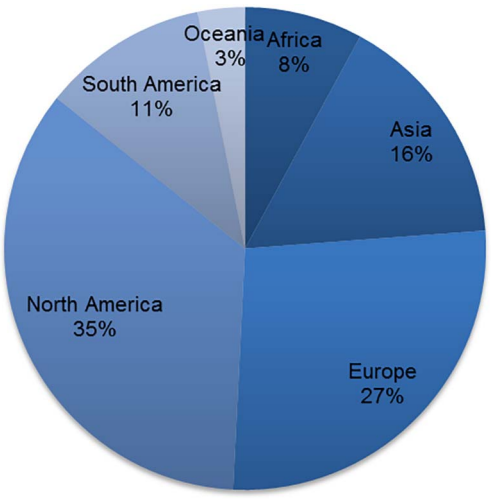


Fig. 1. Geographical distribution of our sample.

correlation, would be applicable in our case. To estimate the correlations, our solution was to use a Tetrachoric correlation coefficient, which is often used in Latent Trait Models but relatively new in factor analysis (Drasgow, 1988).

The second step is to extract the factors. The correlation matrix: $R = (r_{ij})$ $i, j = 1,\ldots,p$ of standardized observations $z_{ij} = (x_{ij} - x_j) / s_j$.

Find values $(l_{i1},\ldots,l_{ik})$, so that $z_i = l_{i1}F_1 + \ldots + l_{ik}F_k + u_i$ (k < p).

Variable i is a linear combination of k factors with "weights" $l_{i1},\ldots,l_{ik}$ plus residual u_i.

L_{ij} and F_j $(j = 1,\ldots k)$ are unknown.

The factor analysis model is

$$Z = Lf + u$$

$$Z = (z_1\ldots, z_p)'$$

$$f = (F_1,\ldots F_k)'$$

$$u = (u_1,\ldots u_p)'$$

$$L = (l_{ij})\ i = 1,\ \ldots,p;\ j = 1,\ \ldots,k$$

L is the matrix of factor loadings.

l_{ij} are the correlations between variable i and factor j.

The sum of squared elements of a row of L denotes the variability of all factors at variable i. The remaining variability is summarized by the residual u_i.

$$\mathrm{var}(z_i) = l_{i1}^2 + \ldots l_{ik}^2 + u_i^2$$
$$= h_i^2 + u_i^2$$

Communality $h_i^2 \in [0,1]$.

The fundamental theorem of factor analysis is described as

$$R = \mathrm{Cov}(z) = \mathrm{E}(zz') = \mathrm{E}(Lf + u)(Lf + u)' = \mathrm{E}(Lff'L') + \mathrm{E}(Lfu') + \mathrm{E}(uf'L') + \mathrm{E}(uu')$$

with assumptions:

$\mathrm{E}(ff') = I$ (factors are uncorrelated)

$\mathrm{E}(fu') = \mathrm{E}(uf') = 0$ (factors and errors are uncorrelated)

$\rightarrow R = LL' + U\ U = \mathrm{diag}(u_1^2,\ldots,u_p^2)$.

The third step is the loading of the optimal number of factors. The Eigenvalues should be greater than unity. Very Simple Structure (VSS) is an alternative procedure to estimate the optimal number of factors (Revelle and Rocklin, 1979). Therefore, it is carried out according to the "Parallel" analysis (Horn, 1965).

The fourth step is the interpretation of factors. It identifies the main difference with principal component analysis. We have adopted the rotation procedures including Varimax, Quartimax, and Promax. Varimax provide the best results in our case.

The fifth step is the computation of factor scores (DiStefano et al., 2009):

$$Z = Lf + u$$

$$\rightarrow F = Z\ R^{-1}\ L.$$

The results of the factor analysis could be used for estimation, with different possibilities for such estimation, such as Regression, Bartlett, Anderson-Rubin, etc. In our research, results will be used for the logistic regression analysis.

3.2.2. Results of Factor Analysis

Among the 63 cities, 28 climate change adaptation actions were identified. To identify the significant actions, we have carried out a factor analysis to eliminate the least significant actions and identify the underlying factors in order to categorize the actions into variables. Before the factor analysis, the actions which only one city used as a response are excluded due to the very insignificant influence of those actions. According to the factor analysis, 24 adaptation actions load onto 6 factors. The following table provides the details of factor descriptions, description of adaptation actions, and factor loading.

There are several ways of categorizing climate adaptation actions (IPCC, 2014) and this study has adopted the categorization from the Fourteenth Chapter of Fifth Assessment Report (AR5) of IPCC, which explains the types of adaptation (physical, social and institutional) and also a more detailed illustration of each category. Our finding has shown that in cities, most of the climate adaptation actions are actually cross-sector and also interlinked between different categories. This is consistent with the AR5 that many of the adaptation actions are also overlapping rather than discrete (Table 1).

Similarly, we have carried out a factor analysis for incentivized stakeholders. The results show that eight indicators load strongly onto four underlying factors, and the resulting scale is highly reliable with the factor loading score range from 0.9 to 0.7. The four groups of loaded factor are (1) management, (2) private actors, (3) employees, and (4) administrative actors (Table 2).

For incentive types, three indicators load strongly onto two underlying factors: (1) Monetary reward and winning prizes, and (2) Non-monetary recognition (Table 3).

4. Results and Discussion

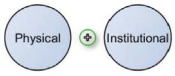
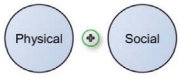
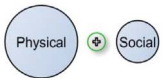
A logistic regression model is carried out to determine the linkage between climate change adaptation and economic opportunities in cities. The dependent variables are the economic opportunities presented in a city. Those with the highest p-values were then eliminated step-by-step, obtaining the results presented in Table 4.

Two variables show the most significance correlated with economic opportunities: climate adaptation plan and GDP. Both adaptation plan (p = 0.014) and GDP (p = 0.040) are positively associated with economic opportunities. Our finding shows that the adaptation plan plays a key role in economic opportunities in cities. This finding provides impetus for our research aim to contribute to the foundational theory that 'It pays for cities to adapt to climate change.' In addition, this result could serve as empirical evidence to support the framework of this theory.

Among four control variables (precipitation, temperature, population, and GDP), only the control of GDP is significant. The current discussion of GDP and climate change usually focuses on how climate change impacts could adversely affect the GDP in terms of the price of inaction (IPCC, 2014). Interestingly, our findings show the advantage of action in terms of how adaptation plans and GDP are positively correlated with economic opportunities in cities. There are several possible interpretations. For instance, more economic opportunities could also mean that climate change adaptation plans bring more funding sources to cities and that fact is captured in both variables (GDP and economic opportunities). The correlation between GDP and economic opportunities could also originate from the green jobs created and external investments attracted to the cities due to its actions towards climate change.

In addition to the two most significant variables, there are also other positively correlated results. The results of the logistic regression analysis show that climate change risks are positively associated with economic opportunities (p = 0.072). This result confirms our proposition that climate change risks could actually better prepare the cities for climate change and, thus, could possibly improve local economic performance by reducing climate hazards and increasing opportunities (Huang-Lachmann and Lovett, 2015). When cities have more risk experiences, they are more prepared for climate change. The effects of preparedness of climate change risks (a) attract investment to the cities and (b) create a more resilient supply chain and infrastructure in cities which reduce losses when impacts take place. This finding has the

Table 1
Factor analysis of adaptation action groups.

No.	Factor description of adaptation actions	Perspective	Adaptation actions	Loading	Main category according to IPCC AR5	Detailed category according to IPCC AR5
1		With long-term perspective	White roofs	0.8	Physical	Ecosystem-based
			Crisis planning and practice exercises	0.7	Social, institutional	Educational, behavioral, government policies and programs
			Maintained and repaired leaking infrastructure	0.7	Physical	Engineered and built environment
			Air quality initiatives	0.7	Institutional, behavioral	Government policies and programs, laws and regulation
			Building resilience and resistance measures	0.6	Institutional behavioral	Government policies and programs, behavioral
			Reduced power consumption	0.5	Institutional, behavioral, Physical	Services, behavioral, government policies and programs, technological
2		With extreme events perspective	Water use restrictions	0.8	Institutional	Government policies and programs
			Disease prevention measures	0.7	Institutional	Government policies and programs
			Storm water capture systems	0.7	Physical	Engineered, technological
			Flood defenses	0.6	Physical	Engineered and built environment
3		With risk perspective	Diversification of water supply	0.8	Physical	Engineered
			Water butts and rainwater capture	0.6	Physical	Technological
			Projects or policies targeted at those most vulnerable	0.6	Social	Informational, educational
			Community engagement education	0.5	Social	Informational
4		With technological perspective	Cooling systems	0.8	Physical	Technological
			Retrofit of existing buildings	0.8	Physical	Engineered and built environment
5		With land-use perspective	Xeriscapes: low water consumption landscaping design	0.8	Physical	Ecosystem-based
			Additional reservoirs and wells for water storage	0.7	Physical	Engineered and built environment
			Awareness campaign/education to reduce water use	0.6	Social	Educational
			Tree planting and green space creating	0.5	Physical	Ecosystem based

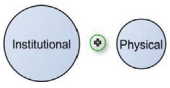
6		With spatial perspective	Shading in public spaces and markets	0.8	Physical, institutional	Built environment, government policies and programs
			Restrict development in flood risk areas	0.7	Institutional	Laws and regulation
			Green roofs	0.6	Physical	Ecosystem based
			Crisis management including warning and evacuation systems	0.6	Institutional	Government policies and programs

Table 2
Factor analysis of incentivized stakeholder groups.

Factor group	Factor description	Incentivized stakeholders	Factor loading
1	Management	Energy managers	0.9
		Environment or sustainability managers	0.9
		Heads of departments	0.8
		Facilities managers	0.8
2	Private actors	Businesses or private sectors	0.9
		Citizens or residents	0.7
3	Employees	All employees	0.9
4	Administrative actors	City agencies	0.9

Table 3
Factor analysis of incentive types.

Factor group	Factor description	Incentive types	Factor loading
1	Monetary and prize incentives	Monetary reward	1
		Winning prizes	0.9
2	Non-monetary incentives	Non-monetary recognition	0.8

Table 4
Results of the logistic regression analysis.

	Coefficient	Standard error	z	p-Value
const	− 2.902	1.734	− 1.674	0.094*
Adaptation plan	2.150	0.874	2.461	0.014**
Risks	2.330	1.293	1.802	0.072*
Physical, social and institutional climate adaptation actions with long-term perspective	− 1.078	0.560	− 1.926	0.054*
Management	− 0.642	0.368	− 1.747	0.081*
Private actors	− 0.700	0.363	− 1.927	0.054*
Population	0.000	0.000	0.366	0.715
Average temperature	0.043	0.084	0.513	0.608
Annual rainfall	− 0.001	0.001	− 0.869	0.385
GDP	0.007	0.003	2.056	0.040**

Mean of dependent variables: 0.777778; Standard deviation of dependent variables: 0.419079.
McFadden R-squared: 0.325906; Adjusted R-squared: 0.026249.
Log likelihood: − 22.49553; Akaike criterion: 64.99107.
Schwarz criterion 86.42241; Hannan-Quinn criterion: 73.42012.
Number of correctly predicted cases = 56 (88.9%).
f (beta'x) with means of independent variables = 0.095.
Likelihood-ratio test: chi-square(9) = 21.7519 [0.0097].
Logit, 63 observations used.
Dependent variable: Economic opportunities.
Standard errors based on Hessian matrix.
* Level of significance: Significant at 90%.
** Level of significance: Significant at 95%.

important implication that a city's experience and ability to learn from the experience to improve its current system are very important and eventually will be visible in local economic opportunities.

A further step to look at the details of climate change adaptation actions in cities and their effects on economic opportunities yielded some surprising results. Firstly, a combination of physical, social and institutional adaptation actions including white roofs, crisis planning and practice exercises, maintained and repaired leaking infrastructure, air quality initiatives, building resilience and resistance measures, as well as reduced power consumption, all actions with long-term perspectives are negatively associated with economic opportunities in cities ($p = 0.054$).

There are some possible explanations. For instance, long-term adaptation actions require capital investment, and the payback or economic benefits only present themselves on a longer time scale. According to the discussion taking place in literature about loss and damage, sometimes certain adaptation actions' costs are not regained (Warner et al., 2012; Warner and van der Geest, 2013). The main contribution of this significant result is to serve the purpose to call for researchers to further study the topic of outcomes of climate adaptation actions in cities.

Further findings have contributed to the debate about motivation crowding theory: our findings show a negative relationship between two stakeholder groups who are entitled to incentives. The two groups are management (energy managers, environment or sustainability managers, heads of departments, facilities managers) and private actors (businesses or private sectors, citizens or residents) with economic opportunities in cities. This result represents preliminary empirical evidence for the debate about motivation crowding theory: incentives could have crowding-out effects, which means that incentives could also have negative effects on environmental and climate change policy (Sandel, 2013). Concerning the incentivized stakeholder group of management and private actors, the findings have revealed their negative relationship to a city's economic opportunities and this shows the crowding-out effects on different stakeholder groups. These findings call for ensuring that stakeholder groups adapt to climate change due to their actual needs and intrinsic motivation instead of for external reasons, such as monetary or non-monetary incentives. They also call for

further research focusing on how different stakeholder groups are motivated to adapt to climate change and the effects of incentives. The crowding-out effects remind policymakers or decision makers to be cautious and strategic with incentives and to evaluate the effects in order to improve their decision-making. Furthermore, this study also calls for more studies on the effects of incentives in climate adaptation in cities.

Certainly, more studies are needed to further study motivation crowding effects to draw a conclusion. Our findings reiterate the idea that it is important to look not just at the incentives themselves, but to look also at who the incentives are meant for. Our findings supported the theoretical foundation of corrosive effects, i.e., that the more incentives are provided to energy managers, environment or sustainability managers, heads of departments, facilities managers, business, private sectors, citizens and residents, the less economic opportunities there are in the cities. Some of the possible explanations originate from the crowding-out theory (Neuteleers and Engelen, 2015; Rode et al., 2015; Sandel, 2013), in which we have to examine the corrosive effects incentives could have on people: do these people take actions to adapt to climate change due to internal motivations (urgency of actions, need for adapting to climatic hazards, reduce weather and disaster risks, increase security and insurance of the vulnerable, etc.) and are we crowding out these internal motivations for external ones (such as more funding sources for the city)? This would be a very crucial angle for future researchers in urban governance studies to develop further.

To sum up, the findings present a very diverse representation of results on both negative and positive relationship between different variables. The findings from a global sample serve as a very important empirical contribution to the economics of climate change adaptation. This paper calls for further economic analysis on empirical evidence of climate change adaptation policy outcomes in cities. Climate adaptation has been implemented at local levels for over a decade, and assessment of outcomes should be part of the formal agenda to obtain a better understanding of climate adaptation policy consequences and results of investments in cities in order to examine our current policy implementation.

5. Research Limitation and Outlook

The results are fruitful and show a wide range of variables to be considered in the economics of climate change adaptation in cities. However, the weakness of the questionnaire design limits the research exploration. First of all, the questions posed about climate change risks, i.e., the difference between experienced and perceived risks, are not differentiated. It is important to differentiate perceived risks and experienced ones as they may lead to different results: the preparedness for climate change could increase the competiveness of cities (Huang-Lachmann and Lovett, 2015). Experienced risks could lead to reducing climate change economic opportunities because of actual losses and damages, while the perceived risks might motivate cities to be prepared for future climate adaptation, which could potentially reduce losses or even increase potential benefits. Therefore, the risks could have been differentiated (Busch, 2011). For the future research agenda, the risks could also be tested as a mediator in the regression analysis to find out whether it motivates cities to be more prepared for climate change. Second, the question asking cities about economic opportunities presented due to climate change could be interpreted very ambiguously. According to the responses, they could just be perceived benefits and subjective instead of net benefits from an economist's perspective. For instance, some of the cities provide examples of their economic opportunities and identify more funding sources as their economic opportunity. However, more funding could actually mean a cost instead of a net benefit to a whole society. Furthermore, the positive and negative relationships between these economic, societal, and climatic variables is a good start to attracting more attention to the fields of studying incentive structure, benefits, and long-term planning of climate change adaptation in cities.

We also would like to point out that even though quantitative analyses are useful, there are certain limitations. This study opens a door and calls for researchers to look further into the details of economic outcomes by carrying out triangulations of methods. The next step in our future research is to conduct a series of interviews with cities from different geographical areas to further investigate what other responses cities could provide aside from public disclosure and self-reporting data, and to better understand what lies beyond the numbers shown in terms of significant results.

6. Conclusion

The study aims to contribute to the research discussion of linkages between economic opportunities with incentives, GDP, climate risks, climate adaptation plan and actions, and climatic variables. In sum, the findings show that a city's climate change adaptation plan and GDP have significant positive relationships with the economic opportunities presented in the cities. Meanwhile, climate change risks also have a positive relationship with economic opportunities. Economic opportunities presented in cities have a negative relationship with three variables, namely one group of climate actions and two groups of stakeholders the city governments give incentives to, i.e. a combination of physical, institutional, and social adaptation actions and incentivized management as well as incentivized private actors.

Our findings show crowding-out effects of incentives: there are significant negative associations between economic opportunities and incentivized stakeholder groups in cities. The findings do not necessarily mean that the funding or monetary incentives should be cut; instead, it calls for a more strategic use of incentives to encourage suitable actions to increase economic opportunities in cities. More importantly, this study calls for more scientific findings, practical tools, and information to support municipal governments in their task to tackle climate change, in order to achieve positive outcomes from their actions in both local climate policy and the local economy.

The findings remind the cities to rethink the motivation to adapt to climate change. Their goals should be a reduction of impacts while exploiting the opportunities instead of competing for more funding. Our study also calls for more studies to include the calculation of social and institutional benefits to incorporate into economic opportunities. Increased incentives do not necessarily bring more economic opportunities. The significant adaptation actions show that a mix of technological and soft solutions could bring benefits. This study also calls for better and more publicly available city-level data.

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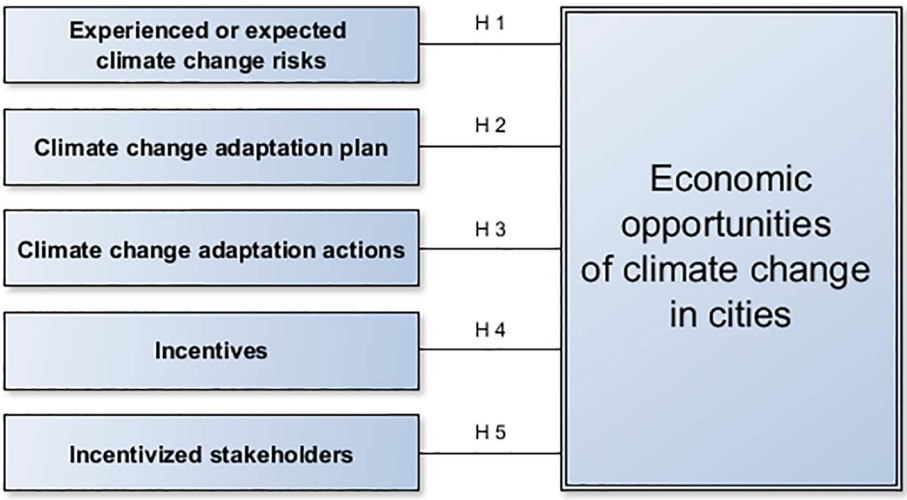
Appendix A



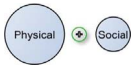
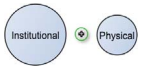
Appendix Fig. 1. Conceptual framework of hypotheses.

Appendix Table 1
Main category and number of coding.
(Source: CDP questionnaires 2012).

Main category	Name of the main category and corresponding sub-category	Number of codings (%)	Question in CDP Questionnaire
I. Risks of climate change	Experienced effects or expected significant physical risks of climate change:		Module: Risks Page: Physical risks
	Yes	58 (92%)	Question 2.0
	No	1 (2%)	
	Don't know	4 (6%)	
II. Climate change adaptation plan	Climate change adaptation plan to increase the city's resilience:		Page: Adaptation
	Yes	44 (70%)	Question 4.8
	No	19 (30%)	
III. Climate change adaptation actions	Climate adaptation actions to reduce vulnerability and expected physical effects of climate change:		Question 4.9 Column 2
	Air quality initiatives	8 (12%)	
	Additional reservoirs and wells for water storage	7 (11%)	
	Awareness campaign/education to reduce water use	10 (15%)	
	Building resilience and resistance measures	11 (17%)	
	Community engagement/education	7 (11%)	
	Community solar projects	2 (3%)	
	Cooling systems	3 (5%)	
	Crisis management (including warning and evacuation systems)	14 (22%)	
	Crisis planning and practice exercises	9 (14%)	
	Disease prevention measures	5 (8%)	
	Diversification of water supply	5 (8%)	
	Drought resistant crops	1 (2%)	
	Flood defenses	20 (31%)	
	Green roofs	12 (18%)	
	Maintained/repaired leaking infrastructure	4 (6%)	
	Projects or policies targeted at those most vulnerable	14 (22%)	
	Promoting low flow technologies	1 (2%)	
	Protect land from development	2 (3%)	
	Reduced power consumption	5 (8%)	
	Restrict development in flood risk areas	3 (5%)	
	Retrofit of existing buildings	3 (5%)	
	Shading in public spaces/markets	3 (5%)	

	Storm water capture systems	18 (28%)	
	Tree planting/creating green space	28 (43%)	
	Water butts/rainwater capture	7 (11%)	
	Water use restrictions	5 (8%)	
	White roofs	6 (9%)	
	Xeriscapes: low water landscaping design	5 (8%)	
IV. Incentives	Stakeholder groups receiving incentives:		Module: Governance
	Heads of departments	3 (5%)	Page: Governance
	All employees	7 (11%)	
	Better buildings partnership or social facilities buildings	1 (2%)	Question 1.1a
	Business or private sectors	5 (8%)	
	Citizens or residents	9 (14%)	Column 1
	City agencies	3 (5%)	
	Energy managers	5 (8%)	
	Environment or sustainability managers	5 (8%)	
	Facilities managers	4 (6%)	
	Schools	2 (3%)	
	Types of incentives used to motivate stakeholders groups:		Question 1.1a
	Monetary reward	8 (12%)	
	Allocated budget	1 (2%)	Column 2
	Federal program	1 (2%)	
	Financial program bank	1 (2%)	
	Financial support	1 (2%)	
	Improved conditions	1 (2%)	
	International/European program	1 (2%)	
	Non-monetary recognition	9 (14%)	
	Tax benefits	3 (5%)	
	Winning a prize	6 (9%)	
V. Economic opportunities	Economic opportunities presented due to climate change in the cities:		Module: Opportunities
	Yes	53 (83%)	Page: Opportunities
	No	5 (8%)	Question 3.0
	Don't know	5 (9%)	

Appendix Table 2
Correlation matrix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1) Economic opportunities	1.00	0.30	0.27	− 0.06	− 0.09	0.13	0.07	− 0.12	0.01	− 0.13	− 0.12	0.07	− 0.02	− 0.04	− 0.09	0.06	− 0.03	− 0.12	0.18
(2) Adaptation plan		1.00	0.18	− 0.03	− 0.16	0.15	− 0.10	− 0.07	− 0.16	0.08	0.11	0.03	− 0.22	0.00	0.15	0.02	− 0.05	− 0.10	− 0.18
(3) Risks			1.00	0.23	− 0.16	0.14	− 0.14	− 0.25	0.09	0.07	− 0.02	0.13	− 0.24	0.12	− 0.01	− 0.04	0.00	− 0.05	0.09
(4) Adaptation actions with long-term perspective				1.00	− 0.04	− 0.11	− 0.09	− 0.08	− 0.07	0.11	− 0.12	0.18	0.01	− 0.06	− 0.22	0.22	0.03	0.06	0.39
(5) Adaptation actions with extreme events perspective					1.00	− 0.03	− 0.16	− 0.06	− 0.11	− 0.09	0.20	− 0.14	0.22	− 0.05	0.00	0.19	0.01	− 0.06	0.15
(6) Adaptation actions with risk perspective						1.00	− 0.16	− 0.01	− 0.07	0.30	0.08	0.01	− 0.04	0.18	0.11	− 0.24	− 0.14	− 0.28	0.07
(7) Adaptation actions with technological perspective							1.00	− 0.08	− 0.01	− 0.10	0.00	0.21	0.03	0.07	− 0.13	− 0.03	− **0.28**	− 0.19	− 0.14
(8)  Adaptation actions with land-use perspective								1.00	− 0.03	− 0.16	− 0.08	0.04	0.19	− 0.23	0.06	0.02	0.19	− 0.12	− 0.14
(9)  Adaptation actions with spatial perspective									1.00	0.09	0.00	− 0.15	0.05	0.19	− 0.20	0.00	− 0.05	0.11	0.07
(10) Management										1.00	− 0.24	− 0.20	− 0.09	0.45	0.22	− 0.11	− 0.02	0.22	0.10
(11) Private actors											1.00	0.06	− 0.17	0.01	0.03	− 0.02	− 0.05	− 0.03	− 0.07
(12) Employees												1.00	− 0.20	0.10	0.37	0.19	0.01	− 0.02	− 0.12
(13) Administrative actors													1.00	− 0.04	− 0.24	0.18	0.17	0.15	0.27
(14) Monetary and prize incentives														1.00	− 0.06	− 0.08	− 0.12	0.14	0.10
(15) Non-monetary incentives															1.00	− 0.09	0.14	0.04	− 0.26
(16) Population																1.00	0.32	0.23	0.33
(17) Average temperature																	1.00	**0.46**	− 0.07
(18) Annual rainfall																		1.00	0.09
(19) GDP																			1.00

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